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is to be found in Ulmus, the serrations of whose leaves become functional when the latter are still very small, or about the time they are emerging from the bud scales. It is not necessary to cut sections to observe this phenomenon, for the leaf margins are of a deep green color, which contrasts strongly with the pale yellowish-green of the remaining portion (*fig. 1*). The serrations appear slightly swollen as though the leaf were thicker in this region than elsewhere. The color contrast remains for a considerable time, or until the leaf has nearly reached its full size.

It requires but a section of a young Ulmus leaf to prove that the serrations really have fully developed spongy parenchyma and functional stomata, while adjacent and other portions of the leaf consist of compact tissue. In *fig. 2* it will be seen that in the right or marginal portion of the section the air spaces are such as would be found in any ordinary mature mesophytic leaf; while on the left of the section, which lies toward the midrib, there will be seen regular rows of cells compactly arranged and evidently in embryonic condition. It will also be noticed that the marginal portion is thicker, in consequence of the development of air spaces.

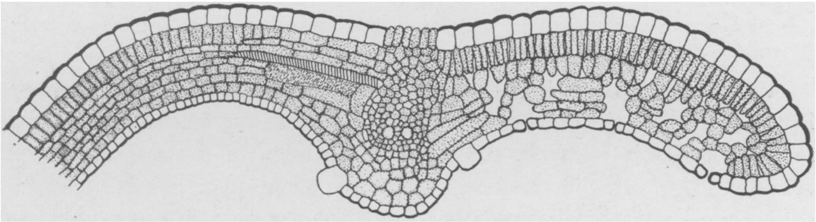

FIG. 2.—Cross-section of a leaf at the margin; the spongy parenchyma on the right is readily distinguishable from the compact embryonic tissue on the left.

It is probable that other instances of precursory leaf serrations will be found, in fact one other was found by the writer, but it was not so well marked a case as that of Ulmus.—FREDERICK H. BILLINGS, *Louisiana State University, Baton Rouge, La.*

THE EFFECT OF DIFFERENT SOILS ON THE DEVELOPMENT OF THE CARNATION RUST.

VARIOUS ideas are held in regard to the rusting of plants, especially the small grains, and to a limited extent asparagus, carnations, and chrysanthemums. The conditions which favor the rusting of such plants as the carnation and the chrysanthemum, plants grown in the greenhouse for the most part, are probably better understood than those which favor the rusting of field crops. However, the conditions that would tend to bring about infection in one place would probably bring it about in the other. Observations made in the field cannot in general be as reliable as those made in the greenhouse, where the conditions of temperature and humidity, important factors in bringing about infection, are to a greater extent under the control of the observer. Observations made in the greenhouse may be duplicated from time to time more readily than can be done in the field.

An example of the rusting of wheat, cited by ROBERTS,[2] seems to indicate that an excess of nitrogen in the soil favors rusting. The many field observations made by STONE and SMITH,[3] on the other hand, indicate that the physical condition of the soil is an important factor in the abundance and distribution of the asparagus rust, the rust being more abundant on asparagus grown in light soils with a low water retentivity, and less abundant on asparagus grown in heavier soils containing more organic matter and with a higher water retentivity.

What are the conditions that produce an abundance of rust, whether in the field or in the greenhouse? Are they excessive food supply in the form of available nitrogen, the physical condition of the soil, favorable conditions for bringing about infection, or some other causes? There cannot be a general distribution or abundance of a rust without a previous general infection; and there must have been a previous development of rust spores with which to bring about such an infection and distribution. There must have been sufficient food furnished by the host so that the rust could mature its spores for distribution and infection. Of course, certain conditions of temperature and moisture are always necessary before germination of the spores and infection can take place.

Some results obtained by the writer, in cooperation with the United States Department of Agriculture, have already been published in *Science*.[4] The present results obtained for the carnation rust, when different kinds of soils were used, are a continuation of the same line of investigation. From previous inoculations of Asparagus, Allium, Dianthus, and Gypsophila, with the asparagus and carnation rusts, the results obtained seemed to indicate that the conditions that were favorable for the development of the host were also favorable for the development of the rust.

A considerable number of inoculations were made on different species of Asparagus and Dianthus. The plants were of different ages and grown in the greenhouse, where they were under control in so far as infection was concerned. The results show that the plants that were making a vigorous growth were more susceptible to artificial infection—inoculation—

[2] ROBERTS, I. P., The fertility of the land. p. 155. 1897.

[3] STONE, G. E. and SMITH, R. E., Ann. Rept. Hatch Expt. Sta. **14**: 1902

[4] SHELDON, JOHN L., Science, N. S. **16**: 397. 1902.

than those that were making little or no apparent growth. A few slowly growing plants were repeatedly inoculated without success until the plants were given extra care and stimulated so that they began to grow more vigorously. Some carnations, grown in small pots, were each inoculated five or six times at intervals of about twenty days, without any of the inoculations being effective. These plants grew very slowly, were slender and produced only one, or at most two, small blossoms.

Certain varieties of carnations are known to be more susceptible to the rust than others; among these are Uncle John and Daybreak. Other varieties are practically immune. The green-leaved varieties are considered by carnation growers to be more susceptible than the more glaucous-leaved ones. The writer has noticed that there was a difference in the period of incubation of the rust when both green- and glaucous-leaved species of Dianthus were inoculated at the same time.

A lack of susceptibility to inoculation, similar to that noted for Asparagus and Dianthus, occurred when seedling onions were inoculated with the asparagus rust. The inoculations were begun as soon as the seedlings appeared above ground, and were repeated at intervals until the seedlings were two months old, when almost every inoculation was successful.

From the results obtained, not only with the rusts referred to, but with other fungi, it would seem that plants, like animals, are not equally susceptible to infection and inoculation at all times. The negative results obtained by other investigators, as well as by the writer, may be attributed in some instances probably to a lack of susceptibility of the host at the time the inoculation was made and not to a failure of the spores to germinate or to the way the inoculation was made. At some other period the same plant might have been susceptible. The state of growth of a plant seems to have much to do with the success or failure following an inoculation, as well as conditions of temperature and moisture which favor the germination of the spores.

It was determined in some of the earlier inoculations that the season, temperature, and sunshine exerted a marked influence on the period of incubation of the asparagus and carnation rusts. It was also thought that the soil made some difference; for when twenty to thirty plants were grown in the same soil, as in a box or large flowerpot, the period of incubation of the rust for each of the plants inoculated at the same time varied only a few hours in most instances, while those that were of the same age and grown in different soils showed more variation.

As a means for testing whether a difference in soils would bring about a difference in the period of incubation of a rust, a stock plant, a green-leaved pink which was known to be very susceptible to the carnation rust, was selected. Sets of cuttings were taken from the stock plant and rooted in river sand. After the cuttings were well rooted, they were transplanted to pots containing the soils to be tested. Each of the soils was carefully mixed before it was put into the pots, so that all would be as uniform in composition as possible. The five soils used ranged from one that was principally sand with a very small amount of organic matter to those containing less sand and more organic matter and clay.

After the plants were potted, they were arranged in sets of five or seven in large saucers, and placed so far as it was possible under the same conditions of light, heat, etc. When the plants had become established and made a growth of a few inches, each set was inoculated. Of the 170 plants inoculated, only three failed to show rust sori in sixteen to twenty-one days, the majority showing sori in seventeen to nineteen days.

The leaves were carefully examined with a hand lens twice a day after yellow spots began to show on them, indicating that infection had taken place. When the uredospores were observed to be breaking through the epidermis of a leaf, a record was entered for that plant. This record was afterward used in making comparisons with the composition of the soils. The Bureau of Soils of the United States Department of Agriculture made a mechanical analysis of the soils and determined the percentage of organic matter and nitrogen.

Rather than depend upon his own judgment, which was liable to have been somewhat biased on account of having watched the development of the pinks and the rust, the writer averaged those of several other persons with respect to vigor, growth, and color of the plants.

The results of the investigation are summarized in part below; the details will be published later. Whether similar results can be obtained by using a different host and parasite remains to be determined.

1. The intensity of color was directly proportional to the amount of clay in the different soils.

2. The growth of the host was directly proportional to the amount of organic matter, nitrogen, and silt in the different soils.

3. The period of incubation of the carnation rust, while not uniform in every instance, was in general inversely proportional to the amount of organic matter, nitrogen, and silt in the different soils, and to the growth of the host; it was directly proportional to the amount of gravel and sand in the different soils; that is, the more gravel and sand there were in a soil, the longer it was before the uredospores broke through the epidermis after an inoculation had been made; and the more organic matter, nitrogen, and

silt there were in a soil, the less time it was before the uredospores broke through the epidermis after an inoculation had been made.

4. Those soils that were favorable for the development of the host were also favorable for the development of the rust; namely those containing the most organic matter combined with silt and clay and a small amount of sand—soils with a high water retentivity, soils rich in nitrogen.

If then the conditions favorable for bringing about distribution and infection were the same for the different soils, the rust should in time be more abundant on those plants grown in a heavy loam where the period of incubation of the rust was least, than on those grown in a light sandy soil, agreeing with the observations made by ROBERTS (*l. c.*) on the wheat rust, rather than those made by STONE and SMITH (*l. c.*) on the asparagus rust. There is a possibility that while the asparagus rust may not have developed so rapidly on the asparagus grown in light soils with a low water retentivity, the greater abundance was due to conditions which were more favorable for bringing about infection. Whether the humidity is greater over sandy soils than over a heavy loam, the writer cannot say from personal observations. Perhaps some one has already determined this factor, which is so important in bringing about the infection of cultivated crops with various parasitic fungi.—JOHN L. SHELDON, *Agricultural Experiment Station, Morgantown, W. Va.*